

15 Sample NTSB Reports Analyzed w/ the HFACS-ME Framework

	Date	Aircraft	Company
1	08/21/95	EMB-120RT	Atlantic SE Airlines
2	01/07/96	DC-9	ValuJet Airlines
3	06/08/95	DC-9	ValuJet Airlines
4	12/14/94	Learjet 35A	Phoenix Air Group
5	03/01/94	B747	Northwest Airlines
6	09/11/91	EMB-20RT	BRIT AIR/ CONT EXP
7	07/19/89	DC-10	United Airlines
8	03/18/89	DC-9	Evergreen Int'l Airlines
9	02/24/89	B747	United Airlines
10	04/28/88	B737	Aloha Airlines
11	05/05/83	L1011	Eastern Airlines
12	09/22/81	L1011	Eastern Airlines
13	09/22/81	DC-10	Air Florida Airlines
14	05/25/79	DC10	American Airlines
15	02/08/76	DC-6	Mercer Airlines

1. This PPT Brief is an individual HFACS-ME breakout of a sample of 15 NTSB reports provided in the hfskyway.faa.gov NTSB Maintenance Accident Report InfoBase. No additional NTSB documentation was used.
2. The results of this effort were summarized in an earlier report entitled: *Human Factors Accident Classification System - Maintenance Extension Analysis of Select National Transportation Safety Board Maintenance Related Mishaps*
3. Some terminology differences with the previous study are the result of changes in the original HFACS-ME taxonomy, The original analysis has been updated and are provided with this individual NTSB case breakout
4. This presentation is meant to be printed out as note pages to accompany the full size slides.

HFACS-ME in Commercial Aviation

- The FAA requested the Navy's School of Aviation Safety to apply HFACS-ME to NTSB mishap cases
- A total of 15 NTSB accident reports that involved maintenance were analyzed using HFACS-ME
- HFACS-ME was successfully used in a post hoc fashion to code existing NTSB reports

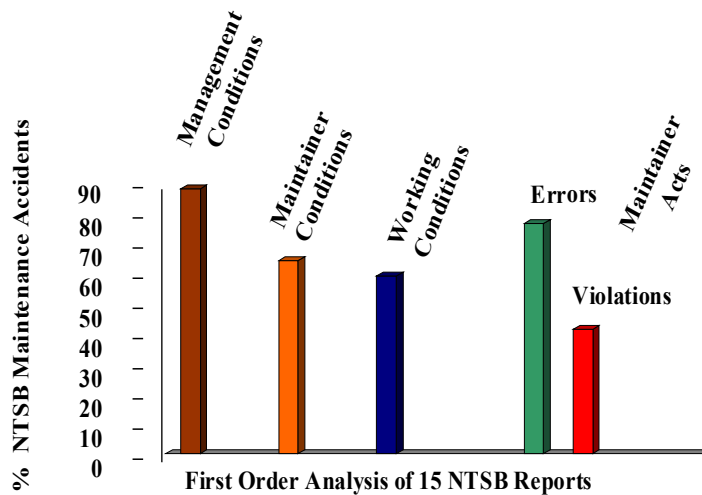
Without reopening an investigation, HFACS was effectively applied to existing NTSB reports.

The NTSB Maintenance Accident Report InfoBase constructed by Galaxy Scientific Corporation for the FAA Office of Aviation Medicine was utilized. It offers full-text search and hyper linking capabilities which are invaluable tools for researchers and users to review past mishaps. The reports were provided by the Honorable John Goglia, NTSB Member.

Procedure. Each mishap case was independently reviewed and the HFACS-ME codes for each case were entered into a spreadsheet for subsequent tabulation. Each causal factor was assigned only one HFACS-ME code, and codes were only assigned to issues clearly identified as having had contributed to the mishap.

Analysis. 15 (63%) reports were selected as clearly having maintenance as a contributing causal factor. Those excluded involved an in-flight lavatory fire, a lightning strike followed by a fuel cell explosion, a fatality from malfunctioning in-flight service equipment, incorrect take-off/approach procedures, and catastrophic engine failures. The mishaps were coded independently by the two judges and achieved an "excellent" level of agreement between the raters.

HFACS-ME Results of NTSB Reports



Results: The conditions observed include inadequate process, documentation, supervision, communications, and training. Consequently they contributed to errors in judgement, knowledge, and attention/memory as well as minor routine or isolated infractions.

The original analysis focused on the primary and contributing factors spelled out in the NTSB report executive summary and discussion. There were a total of 36 maintenance factors listed in the 15 accidents (average 2.4 factors per case). The follow-up analysis which carefully sifted through all of the cases came up with 150 latent conditions (average 10 per case) that set the stage for 55 unsafe acts (average 3.7 per case). This indicates that the reports do not consistently call out all potential contributing factors that are identified during an investigation. Though these may not be major factors, their potential for reducing the chances of an incident or mitigating its consequences is not to be underrated.

Breakout:

Management Conditions – All of the 15 NTSB mishaps reported both having a Management Conditions that set the stage for an unsafe act and/or maintenance condition. The majority of management issues involved inadequate procedures, documentation, design, supervision, and operations.

Maintainer Conditions – 73% of the 15 NTSB mishaps reported Maintainer Conditions. The majority of maintainer issues encompass inadequate communication, adaptability/flexibility, and training/preparation.

Working Conditions – 67% of the 15 NTSB mishaps reported Working Conditions. The majority of maintainer issues cover inadequate lighting/light, unavailable/inappropriate equipment, and confining/obstructed workplace.

Maintainer Acts – 87% of the 15 NTSB mishaps reported Maintainer Errors, whereas 47% had Violations. Errors were fairly equally divided among all categories, and most violations were minor.

Conclusions:

The HFACS-ME was effective in capturing the nature of, and relationships among, latent conditions and active failures present in these NTSB cases. The insights gained provide a solid perspective for the development of potential intervention strategies.

HFACS-ME (Atlantic SE - EMB-120RT, 1995)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Notes: This accident is centered around maintenance at the propeller repair facility; no airline aircrew or maintenance actions were reported causal to this accident. The aircraft axe was the wrong type, which resulted in additional injury to the cockpit crew in the post-crash fire, but was not a factor in the “maintenance accident” itself. As such, it was NOT included in this analysis under “inappropriate equipment”. It would be addressed in the full accident report.

Management Conditions

Organizational

Inadequate Processes (Yes)- Bore scope effectiveness; Inadequate corrosion inspection methods and interval; Hamilton Standard Engineering Department changes to PS960A allowing blending of taper bores without visible damage or prior shotpeening; FAA not informed of procedural changes to PS960A; FAA/Hamilton Standard allowed termination of taper bore inspections after only a visual inspection; FAA Advisory, AC20-66, should reflect testing of older propellers’ vibrations; overall procedures for testing propeller vibrations; FAA acceptance of EMB-120 nacelle/gear box design failures following full or mid-blade losses; Internal/External Communications and Coordination; lack of training on document changes; FAA certification requirements for repair facility technicians

Inadequate Documentation (Yes)- Confusion between PS960A and “accepted procedure” documented in the memorandum to blend taper bores that did not have previously noticeable damage; no photos of corrosion/faults for inspectors and workers of prop taper bores

Inadequate Design (Yes)- EMB-120 nacelle (RGB and nacelle fail with loss of ½ of blade); propeller vibrations (testing issue); corrosive problem of chlorine impregnated cork (corks removed in 1994 prior to this accident, but chlorine corrosive effect remained afterwards)

Inadequate Resources (Yes)- Manning: the technician who performed the blade repairs worked an additional 8-26 hours of overtime each week during the previous two months; training on blade repairs conducted by the Engineering Manager who had never seen a taper bore crack; training materials (photos, models, videos)

Supervisory

Inadequate Supervision (Yes)- No post-work inspection of propeller blending; unsupervised taper bore blending with 90 hrs of training (vice 250 hrs practiced on other tasks)

Inappropriate Operations (Yes)- Unsupervised maintenance; Inadequate manning/training; “accepted” blending procedures inconsistent with original intent of PS960A and not verified; no inspection of non-certified technician’s work

Uncorrected Problem (Yes)- Residual problem of chlorine corrosion from taper bore cork; No re-inspection of blades after discovery of earlier inadequate processes

Maintainer Conditions

Medical

Physical State (Yes)- Possible factor because of the technician’s overtime of 8-26 hours extra per week; NTSB also noted that borescope lighting can cause eye strain (although not definitely attributed to this accident).

Crew Coordination

Communication (Yes)- FAA/DER/ENG Dept. on PS 960A modifications (written and verbal)

Adaptability/Flexibility (Yes)- Repair technicians job change from nickel plate/blade repairs to taper bore repairs without similar amounts of training or supervision; Manning shortfalls; Modifications to PS960A procedures caused confusion

Readiness

Training/Preparation (Yes)- No training on “modifications” to PS960A; Technician’s 90 hrs vice 250 hrs of training on new task of taper bore repairs; Inadequate training materials (no corrosion photos/models); Inadequate training on taper bore blending repairs

Certification/Qualification (Yes)- Technician was not qualified with sufficient skills/training to conduct the taper bore work and sign it off alone (90 hrs vice 250/poor training); Technician was not certified, but this wasn’t required by the FAA (see inadequate processes for the FAA on this issue)

Working Conditions

Environment

Lighting/Light (No). Inadequate Borescope lighting is an equipment factor

Equipment

Unavailable/Inappropriate (Yes)- Borescope with inadequate lighting causes eye strain and poor detection rates; Blending tools left scored finishes that did not induce fatigue but decreased the discovery of cracks

Maintainer Acts

Error

Attention/Memory (Yes)- Failed to notice crack of detectable size

Knowledge/Rule Based (Yes)- Lack of training on “modifications” to PS960A procedures.

Skill/Technique (Yes)- No crack found during visual inspection; post-visual inspection sanding work was rough enough to mask later visual and ultrasonic evidence of a crack

Violations

Routine (No). Although the modified PS960A procedures were not adequately incorporated and communicated at the management levels, the technician and manager were following what they believed were approved procedures.

HFACS-ME (ValuJet - DC-9, 1996)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
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Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
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	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
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Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Notes: The NTSB report focuses mainly on aircrew and non-maintenance factors. Unfortunately, the repair facility working conditions and maintainer acts are not discussed in the report. This analysis is therefore limited to maintenance documentation, organizational processes, and communication of mechanical issues from the cockpit to Maintenance.

Management Conditions

Organizational

Inadequate Processes (Yes)- FAA oversight of ValuJet procedures and operations; FAA/ValuJet should have recognized and developed cold weather nose gear servicing procedures similar to the DC-9 maintenance manual; Reliance on aircrews to check strut servicing acceptability during preflight inspections

Inadequate Documentation (Yes)- ValuJet maintenance manual and winter operations section of the revised manual failed to contain nose gear shock strut servicing procedures that reflect the manufacturer's guidance.

Supervisory

Inadequate Supervision (Yes)- The POI and PMI were current for FAA requirements for their positions, but neither had previous DC-9 experience which led to airline procedure problems (POI referred DC-9 issues to qualified FAA inspectors, however); PMI was unaware of the DC-9's history of problems with underserviced/underinflated nose gear shock struts and unaware of the manufacturer's cold weather operations procedures

Inappropriate Operations (Yes)- Relying on flight crew strut checks.

Uncorrected Problem (Yes)- ValuJet had 20 of 46 outstanding FAA inspection violations at the time of the report (procedural and organizational issues)

Maintainer Conditions

Medical (Unknown).

No individual maintainer at the rework facility or at the airline was discussed in the NTSB report.

Crew Coordination

Communication (Yes)– Pilots should have radioed back to Systems Operations Control to get assistance from Maintenance on the gear and circuit breaker technical issues; ValuJet had only a cockpit-oriented CRM program vice an integrated CRM program that should have included communications with external sources (Maintenance, Operations, etc.) So, although no individual maintainer was discussed in the report, communication with Maintenance was a factor because no one in Maintenance was ever asked for assistance

Working Conditions

Environment (Unknown).

It was cold weather servicing, but no information was given on the maintainer's conditions.

Maintainer Acts

Error (Unknown).

An error certainly was made in nose strut servicing, but if the maintainer followed the inadequate airline procedures, he/she did not make the error...the procedures were the error .

HFACS-ME (ValuJet - DC-9, 1995)

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Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
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Notes: Most of the factors relate to the foreign company Turk Hava Yollari (THY) that sold the accident engine to ValuJet. Accordingly, their factors would fall under Management-Organizational issues in the chart above in ValuJet's viewpoint. Additional comments are provided should one consider another HFACS-ME chart from THY's viewpoint.

Management Conditions

Organizational

Inadequate Processes (Yes)- THY failed to perform proper inspections of disks and missed a detectable crack; THY training was conducted by fellow workers; THY did not have an adequate record keeping system; THY failed to use "process sheets" to document overhaul procedures; FAA needs to regulate the various industry usage of "serviceable tags" and foreign repair station documentation requirements; THY ineffective use of green wire to mark components that have been inspected (wire found on non-inspected components); disk Stress Reduction holes were not inspected at THY along with the tie-rod holes due to perceived confusion on Pratt & Whitney Manual; Pratt & Whitney recommended that THY translate process sheets to Turkish even though workers spoke English well and were knowledgeable; THY did not clarify Manual confusion with Pratt & Whitney

Inadequate Documentation (Yes)- Documentation was inadequate following aircraft/ engine/part purchase from THY(tags); Pratt & Whitney Manual was specific but hard to understand with illustrations that did not show the stress reduction holes along with the tie-rod holes for inspections (NTSB discounted this as a factor even though they stated the document was confusing and issued a Safety Recommendation to change the wording; also the THY personnel stated that it was confusing which resulted in the Stress Reduction holes not being inspected); THY had no documentation on what type of inspections were performed on the accident compressor disk; ValuJet's maintenance manual did not include specific instructions for conducting humidity inspections during storage; FAA guidance insufficient on required detail for maintenance records

Inadequate Resources. Yes. FAA PMI staffing shortages led to 2YR renewal intervals for THY; PMI for THY was responsible for 21 European repair stations

Supervisory

Inadequate Supervision (Yes)- ValuJet shipped the engine to their Dee Howard facility for installation on an aircraft without proper tags. Also, at THY supervision was lacking if “green wire” labeling, documentation, and inspections were not conducted appropriately

Inappropriate Operations (Yes)- Engine did not undergo humidity inspections every 30 days while stored by ValuJet

Supervisory Misconduct (Yes)- The ValuJet Quality Control inspector on site (at Dee Howard facility) certified the accident engine as airworthy without reviewing engine records or a serviceable tag

Maintainer Conditions

Medical

Mental State (No). Complacency was a possible factor during the disk inspection at THY, but not at ValuJet itself

Crew Coordination

Communication (No). THY should have communicated with P&W/FAA on P&W Manual confusion

Assertiveness (No). THY again, should have verified P&W Manual requirements

Readiness

Training/Preparation (No). ValuJet maintenance training was not discussed, however, THY’s training did have shortfalls (Management-Organizational-Inadequate Processes)

Maintainer Acts

(No specific maintainer acts discussed for ValuJet. Comments provided for THY factors)

Error

Attention/Memory (No). Even if Stress Reduction holes were not rigorously inspected with the tie-rod holes, their proximity and the size of the crack should have allowed the crack to be detected at THY

Knowledge/Rule Based (No). At THY this issue is still unresolved at their maintainer level concerning the confusion over the P&W Manual

Skill/Technique (No). THY inspectors, however, failed to discover the crack either by attention or skill.

HFACS-ME (Phoenix Air - Learjet 35, 1994)

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Management Conditions

Organizational

Inadequate Processes (Yes)- USAF oversight was considered by the NTSB to be “less comprehensive than FAA oversight of Part 135 aircraft operators” – this appears in the NTSB report’s Analysis and Recommendations sections, but not in the Conclusions

Inadequate Documentation (No). Although modified after the accident, FAA Form 377 was adequate for the wiring task and was utilized effectively by the previous operator to correctly wire 3 of 18 aircraft – it simply wasn’t referred to by the mechanics and inspectors of Phoenix Air

Supervisory

Inadequate Supervision (Yes)- Phoenix Air’s Maintenance Department failed in overall supervision given that 15 aircraft were wired incorrectly; Phoenix Air mechanics and inspectors routinely compared aircraft maintenance tasks to other completed aircraft vice using appropriate manuals and forms; Phoenix Air Maintenance failed to curtail these routine violations

Inappropriate Operations (Yes)- Provided information (Form 377, etc.) was not used in the performance of tasks

Uncorrected Problem (Yes)- Multiple opportunities existed to discover and correct previous aircraft wiring errors during the mechanic/inspector referral to those aircraft as models for further maintenance; maintenance and inspection practices were left uncorrected to the point that a lack of document use in inspection became routine violations

Supervisory Misconduct (Yes)- Blatant disregard of referral to Form 377 by the accident inspector who chose instead to use another aircraft to judge task acceptability

Maintainer Conditions

Crew Coordination

Communication (Yes)- During the first Phoenix Air aircraft wiring modification, the mechanic who tried to clarify the wiring requirement was told to “put it there”, however, with the confines of the hell hole, he thought the other mechanic was pointing to the battery bus instead of the generator bus – this aircraft became the “model” for the following 14 incorrectly wired aircraft

Assertiveness (No). Nothing suggests that anyone felt restrained from questioning maintenance practices and “everybody worked well together” according to the inspector

Adaptability/Flexibility (Yes)- Use of another aircraft to verify correct accomplishments of maintenance tasks, instead of the correct documents, is a failure of adaptability/flexibility

Readiness

Training/Preparation (Yes)- Although certified, experienced, and generally well trained, none of the mechanics and inspectors who reportedly knew how to complete the wiring task were actually trained in that task and obviously did it incorrectly; The accident aircraft inspector was certified and experienced in other aircraft but had no training on the Learjet

Working Conditions

Workspace

Confining (Yes)- The “hell hole” was described as confining and was cited as a reason that the communication failure occurred on the initial incorrectly wired aircraft

Maintainer Acts

Error

Judgment/Decision-Making (Yes)- The accident mechanic, the accident inspector, and all other mechanics/inspectors on previously incorrectly wired aircraft all failed in their judgment and decision making on utilizing model aircraft instead of pubs; All who were certified A&Ps should have had better judgment on attaching the wires directly to the battery bus without visible circuit protection/surge elimination

Knowledge/Rule Based (Yes)- No one followed Form 377 that detailed the proper method of wiring.

Skill/Technique (No). The error was in judgment and procedure, not in skillful use of tools, equipment, or technique

Violations

Routine (Yes)- Both the mechanics and the inspectors routinely used other aircraft as models to determine maintenance acceptability vice referral to manuals, forms, etc.

HFACS-ME (Northwest - B747, 1994)

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	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Management Conditions

Organizational

Inadequate Processes (Yes)- Required the use of CITEXT cards despite known discrepancies; Did not adequately incorporate CITEXT system use and training and did not use inspectors in the CITEXT review process; Continued operations with known manning/training/procedural inadequacies; Over-reliance on OJT; Airline did not build a safety culture which allowed routine maintenance shortcuts; FAA did not adequately monitor maintenance, inspections, production planning or the hangar's human factor discrepancies (lighting/scaffolds)

Inadequate Documentation (Yes)- CITEXT Cards did not match the GEMM (which was adequate); Confusing Fuse Pin Retainer requirements; Inadequate red tag requirements; No turnover checklists

Inadequate Design (Yes)- NTSB suggestion of painted fuse pins to reveal missing retainers; Possible scaffolding design issues as well

Inadequate Resources (Yes)- Lack of Storage; Poor Scaffolding; Inadequate Lighting; Director of Training position was vacant and staffed by a temporary director; Insufficient personnel for weekend shifts; FAA did not have enough inspectors

Supervisory

Inadequate Supervision (Yes)- Could not identify who/when/why on primary retainer removal; CITEXT card failures not adequately addressed; Failure to ensure adequate final inspection; Insufficient red tag tracking; Ineffective planning of compartmentalized tasks

Inappropriate Operations (Yes)- Continued use of hangar 6 lights/scaffolds with known safety and effectiveness hazards; Over-compartmentalization of maintenance tasks; Poor scheduling/combining of maintenance crews during weekend shifts; Inspectors overworked

Uncorrected Problem (Yes)- CITEXT Card use and training; Failure to utilize Red Tags on a routine basis; Inadequate lighting, scaffolds, parts storage and housekeeping; Trained personnel shortages; Ineffective scheduling

Maintainer Conditions

Medical

Mental State (Yes)- The “OK to Close” inspector felt pressured to get the job done; Complacency/frustration with CITEXT work cards; Anxiety/confusion of weekend crews who were unfamiliar with tasks and crew assignments

Physical State (Yes)- The “OK to Close” inspector was fatigued from working all night without break

Crew Coordination

Communication (Yes)- Director of Maintenance’s written complaints on procedural errors were ineffective in changing maintenance actions; Compartmentalized tasks inhibited communication of any kind; Insufficient use of verbal, visual (tag), or written communication (documentation of work cards)

Assertiveness (Yes)- Director of Maintenance did not effectively stop procedural violations; Person who removed the primary retainer never notified others before or after the accident; No one demanded re-inspection of the No.1 pylon after retainers were found not installed in the No. 4 pylon

Adaptability/Flexibility (Yes)- Multiple tasking and compartmentalization failures; Changing crew assignments and shift schedules promoted confusion

Readiness

Training/Preparation (Yes)- OJT failed to adequately standardize red tag and other non-standard procedures

Certification/Qualification (Yes)- There were no certification issues, but the NTSB cited qualification problems with maintenance and inspections

Working Conditions

Environment

Lighting/Light (Yes)- Lights were over sprayed with paint in hangar 6

Environmental Hazards (Yes)- Fall hazard from “wood bridges” on scaffolding, especially while carrying additional lighting due to poor permanent lighting

Equipment

Damaged/Unserviced (Yes)- Scaffolds and lights

Workspace

Confining (Yes)- Inspectors had difficulty accessing the work areas near the pins/retainers from the scaffolding

Obstructed (Yes)- Missing retainers could not be easily noticed due to accessibility/visibility problems when using scaffolding with poor lighting

Maintainer Acts

Error

Attention/Memory (Yes)- No one noticed the removal of the primary retainer; The mechanics and inspectors did not notice the missing retainers prior to and during the “close up inspection”; The bag of retainers was not noticed until after the accident

Judgment/Decision-Making (Yes)- Red tags were not used in questionable cases (during all work on this accident); No one chose to re-inspect the No. 1 pylon after finding and reinstalling the bag of retainers for the No. 4 pylon; The inspectors chose to conduct less stringent inspections (this is not a violation, because they were still within their guidelines)

Knowledge/Rule Based (Yes)- The NDT inspector, and others, were confused on the requirements for secondary retainers; Red tag procedures were not standardized

Violations

Routine (Yes)- Storing/stacking parts together in areas that could damage the equipment and inhibit parts accountability

Infraction (Yes)- Not documenting/red tagging maintenance when specifically required just to save time and effort; Inspection short cuts.

Exceptional/Flagrant (Unknown)- Violations of this nature are not discussed in this NTSB report, but since there is absolutely no knowledge, admittance, or documentation of the primary retainer removal, there is a small possibility of a deliberate act. This should be thoroughly investigated and clarified in the report to eliminate future questions.

HFACS-ME (BRIT AIR/CONT EXP- EMB-120, 1991)

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Management

Organizational

Inadequate Processes (Yes)- There is consistent evidence of improper maintenance practices, turnover violations, and documentation failures; There are also discipline and certification issues concerning the inspector who removed the screws and was previously warned; Upper management failed to track and correct these safety issues and failed to foster an overall safety culture; The FAA overburdened the sole PMI by not augmenting his manning, by requiring him to train his subordinates (and relief), and by relying too greatly on paperwork surveillance of maintenance practices

Inadequate Documentation (Yes)- There was ambiguity between the manufacturer, the FAA, and the airline on the specific identification of published Required Inspection Items (RIIs); The work card even had "yes" circled by the RII, but organizational procedures contradicted the card; Also, there is no documentation that requires notification of aircrews concerning critical maintenance repairs (Note: the General Maintenance Manual, or GMM, was adequate but not followed. Failure to use a manual could fall under several other categories)

Inadequate Resources (Yes)- The maintainers were not provided with sufficient hangar space and/or outside lighting to adequately conduct the expected maintenance; Although the evidence is not clear in the case study, the hydraulic lift may not be satisfactory for maintenance on top of the T-tail (If this happened routinely and was either ignored or expected by upper management, you would have a strong case to also categorize this as Inadequate Processes. The current evidence suggests that it happens very rarely.); The FAA provided insufficient personnel to conduct inspections on the growing airline; The NTSB dissenting statement further cited a lack of a Lead Mechanic and a Lead Inspector.

Supervisory

Inadequate Supervision (Yes)- Supervisors and inspectors not only failed to monitor and enforce published procedures, they were some of the key violators; Improper documentation of maintenance actions, turnover failures, poor control of parts (screws) and frequent shifts in schedules and team composition were directly causal to this accident

Inappropriate Operations (Yes)- A conscious decision was made by the second shift supervisor to begin work on the deice boots without using the work cards; The aircraft was purposely moved outside, in the dark, so that additional maintenance could be conducted on another aircraft

Uncorrected Problem (Yes)- Routine turnover and documentation issues were allowed to continue without significant correction; Discipline and certification of the second shift inspector created a culture in which safety errors and violations were becoming the norm

Supervisory Misconduct (Yes)- The second shift supervisor directed that the boot replacement begin without the use of work cards; Inspectors conducted maintenance; Supervisors left work without conducting adequate turnovers

Maintainer Conditions

Medical (Unknown).

The NTSB said there were no drug/alcohol problems and no background or behavioral issues. There is also no evidence of any problems with limitations in physical size or strength. And finally, although maintenance was done during the evening and night shifts, there is no evidence in this case study to suggest fatigue.

Crew Coordination

Communication (Yes)-. Verbal and non-verbal communication failures dominated the shift turnovers; Pilots also had no notification of repairs.

Assertiveness (Yes)-. Supervisors, inspectors, and mechanics all failed to demand appropriate turnovers; Second Shift mechanics did not demand work cards from their supervisor when they began the boot repairs to assist the Third Shift; And, the final installation was completed outside in the dark...no one demanded additional lighting or repositioning of the aircraft back in the hangar

Adaptability/Flexibility (Yes)-. The second shift started the boot replacement without work cards to help the third shift; The inspectors became mechanics by assisting with the maintenance tasks (removing screws/installing deice lines); The aircraft was moved/repared outside to accommodate more maintenance within the hangar

Readiness

Training/Preparation (No). Deficiencies were noted in the report. In fact, procedures were generally known.

Certification/Qualification (Yes)- but only in respect to the continued qualification of the Second Shift inspector who was warned twice in the previous month and failed to show much improvement when he removed the screws without an adequate turnover.

Infringement (or violation) No. This category includes issues such as intoxication, but all maintenance personnel tested negative on drug and alcohol abuse.

Working Conditions

Environment

Lighting Yes. Lighting was poor outside the hangar where the final maintenance was conducted. The final inspector, who gained access to the T-tail to reinstall the right side deice lines, did not even notice the missing screws on the left side due to the darkness.

Equipment

Unavailable/Inappropriate (Yes)- Lights were not available outside the hangar; Hydraulic lifts were available to access the T-tail, but both inspectors climbed on top of the stabilizers. More information is needed to find out if the available lifts were inadequate, damaged that they could not be raised higher, or the inspectors simply chose to climb onto the T-tail.

Workspace

Confining (Yes)- The aircraft had to be moved outside because the hangar was too confining to bring in the other aircraft; The maintenance on the aircraft itself had no problems of confined spaces near the T-tail

Obstructed (Yes)- The missing screws could not be seen from the hangar floor due to the tail's height and their location on the top of tail (obstructed view); The inspectors climbed onto the aircraft's tail to access the screws and deice lines (possible obstructed access, depending on hydraulic lift issues discussed previously)

Inaccessible (No). Although the inspectors climbed onto the tail, it was still accessible. If they couldn't reach or see something at all, then it would be a factor

Maintainer Acts

Errors

Attention/Memory Attention (Yes)-The final inspector did not notice the missing screws (aggravated by darkness); The mechanics who replaced the screws did not think to check all work areas for missing screws when, even though they used both old and new screws, they "only" had a dozen old screws left. **Memory (No).** but possible. Memory failures on turnovers could have occurred, but the evidence currently points to decisions among the supervisors to avoid turnovers and appropriate procedures

Judgment/Decision-Making (Yes)- The second shift supervisory exercised poor judgment by starting the boot replacement without work cards; The decision to move the aircraft to an unlighted area for final repairs and inspection.; Also, assumptions made during turnovers without verification, to name a few; For a non-cause factor "hazard": the decision to use makeshift tools when conducting the elevator balance

Knowledge/Rule Based (No). In general, procedures were known, but often ignored or "modified" (e.g., violations).

Skill Based (No). There is no evidence of skill based errors on this case (e.g., no one damaged anything by being overly rough or untrained). However, the Second Shift inspector may have made a skill based error (as well as others) last month when he "missed a crack in an engine exhaust stack". Because it was not causal to this mishap, and he had no other skill based errors on this accident, it would be classified separately as a hazard vice a cause factor.

Violations

Routine (Yes)- The lax turnover procedures and inadequate documentation were not corrected; The organization had appropriate regulations, but they were routinely violated, possibly due to complacency, lack of discipline, and an overall inadequate safety culture (further investigation necessary); Inspectors conducted maintenance.

Infraction (Yes)- Two events describe non-routine rule bending to save time: The Second Shift Supervisor started the repairs, without cards, to assist the Third Shift (normally they used work cards); The aircraft final repairs were conducted outside to expedite repairs on another aircraft in the hangar (they initially planned to do all of the work in the hangar)

Exceptional (No). Although there were numerous violations of procedures, the intent and severity point towards Routine Violations and Infractions. There does not appear to be a conscious attempt to falsify inspections or maintenance actions.

Flagrant (No). Despite the severity and amount of routine procedural violations and infractions, they were not blatant acts which defied authority and all consequences.

HFACS-ME (United - DC-10, 1989)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Notes: The NTSB discusses general human factor errors in fan disk production, but does not interview inspectors or adequately specify human factor problems associated with the accident disk

Management Conditions

Organizational

Inadequate Processes (Yes)- Vacuum-melt process is not adequate for production of disks due to contamination; Vacuum-melt process was changed from two to three melts after production of the accident disk; Hard Alpha defect was created in fan disk during manufacture; Defect not discovered during ultrasonic, macrotech, and FPI inspections during manufacture; Cavity/cracks formed during final manufacturing and shot-peening process after ultrasonic/other inspections and no final inspections were conducted; Disk bore inspection process is inadequate; United conducted an FPI 760 hours prior to accident and failed to find an estimated ½ inch crack; Aviation industry has minimum redundancy built into the FPI process; NTSB believes that NDI processes should be simplified or automated and require a “second set of eyes” oversight

Inadequate Documentation (Yes)- Disk forging origin could not be verified from TIMET and GEAE documentation which made it difficult to determine forging errors and prevent similar batch (“heat”) failures in other aircraft

Inadequate Design (Yes)- Engine containment issues. Disk design was acceptable but the production process was inadequate

Supervisory

Inadequate Supervision (Yes)- United conducted an FPI 760 hours prior to accident and failed to find an estimated ½ inch crack; Inspectors generally work alone with little supervision; no “second set of eyes” according to the NTSB

Maintainer Conditions

Readiness

Training/Preparation (No). NTSB said training/certification was adequate.

Working Conditions

Equipment

Unavailable/Inappropriate (Yes)- NTSB stated that Eddy current inspections would have improved the likelihood of detection of cracks

Workspace

Confining (Yes)- Constrained use of tools and inspection techniques (the presence of the corner radius between the inside diameter of the bore and the front face of the bore makes it difficult to bring an ultrasonic probe close to the corner)

Obstructed (No). Possible view obstruction of portions of inspected disk when suspended by cables during inspection. Disk is rotated however, so that entire disk area is viewable. This would therefore be an attention or skill issue while rotating the viewing area.

Maintainer Acts

Error

Attention/Memory (Yes)- Defects not discovered during manufacture; United inspector missed a 1/2 inch crack in the disk

Judgment/Decision-Making (Yes)- NTSB stated that the United FPI inspector may have given only a cursory examination of the disk bore area because cracks are normally only found in the dovetail areas

Skill/Technique (Yes)- Although no inspector or manufacturer was interviewed or individually discussed, the skills and techniques of those who handled the disk are questioned

HFACS-ME (Evergreen - DC-9, 1989)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Notes: There is no discussion of specific maintainer acts on this accident. The aircrew, particularly the first officer, was responsible for verification of cargo door locking. As such, I will try to address this accident as a “ramp” accident with aircrew actions included prior to departure.

Management Conditions

Organizational

Inadequate Processes (Yes)- Airline/FAA procedures for cargo door lock verification procedures; FAA failed to mandate modifications to cargo door, vents and warning system; Door Handle Labeling; Service Bulletin review/incorporation between multiple operators of the aircraft particularly with usage/configuration changes; Training on door lock inspection requirements (changed to inspect from ground vice passenger door after the accident)

Inadequate Documentation (Yes)- A training document was added to clarify locking procedures

Inadequate Design (Yes)- Unmodified warning system was wired in parallel and could give a false indication (even if it wasn't corroded); Cargo door operators have no direct indication from the door control panel that locks actually engage which requires the internal observance of latches (inaccessible in this case) or external to the aircraft (misabeled on this aircraft); Modifications to design were made (but not incorporated)

Supervisory

Inadequate Supervision (Yes)- Door handle labeling was not aligned properly and was never corrected

Inappropriate Operations (Yes)- Approved procedure of checking the status of the cargo door lock from the passenger door area was unrealistic, particularly with routine night operations and dark green paint scheme at the cargo handle area

Uncorrected Problem (Yes)- Cargo door lock was incorrectly labeled

Maintainer Conditions

Crew Coordination

Adaptability/Flexibility. Yes. Company authorized inspections of the cargo door lock from the passenger door was a corporate failure in adaptability/flexibility; First officer did not personally check cargo door from the ground or ask others to do so. No direct maintenance A/F issues were noted in the report.

Readiness

Training/Preparation. Yes. NTSB noted that training was adequate with the exception of the company interpretation of cargo door latch visual examination procedures.

Working Conditions

Environment

Lighting/Light (Yes). With a mislabeled cargo door handle, personnel had to rely on the position of the handle which was difficult to see at night with a dark green painted background. No issues of lighting on maintenance of the aircraft were noted.

Equipment

Damaged/Unserviced (Yes). Door warning system was corroded which gave a false safe indication

Unavailable/Inappropriate (Yes). Modifications to door warning systems (serial wiring and vent SBs) were not incorporated

Workspace

Not an issue for maintenance, but the following notes are relevant to operators:

Confining (No). The cargo door area was blocked with cargo, but operation was not inhibited. The latch verification was Inaccessible, however.

Inaccessible (Yes)- Internal (alternate) method of lock verification was inaccessible because of cargo placement. Operators had to rely on external verification.

Maintainer Acts

Error

Attention/Memory (Yes)- First officer and the ground maintenance personnel noted incorrectly that the cargo door was secure

Judgment/Decision-Making (Yes)- Operator (first officer) did not activate closing cycle long enough to lock the door; First officer and ground maintenance technician only checked the cargo door lock from the passenger door area during night operations

Knowledge/Rule Based (No). The cargo door lock verification from the passenger area was an approved procedure, though inadequate. The first officer was in compliance from the airlines perspective.

HFACS-ME (United - B747, 1989)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Management Conditions

Organizational

Inadequate Processes (Yes)- NTSB stated Boeing and FAA did not provide a timely response following previous cargo door opening incidents; UAL had no procedures for using viewing ports to check latch cams; UAL/FAA (original) PMI approval of air-driven torque-limiting screwdrivers to open inoperative cargo doors; FAA (new) PMI and FAA B-747 maintenance inspector did not review or check United's MEL because they assumed the previous inspectors did; Boeing's design and FAA's certification of door locking mechanisms; United's Trend Analysis failures to further investigate cargo door repeat problems from the previous months; Boeing's Failure Analysis of cargo door

Inadequate Documentation (Yes)- UAL's maintenance manual differs from Boeing's manual by not including "viewing port" latch cam confirmation or confirming that the cargo door warning light goes out on the flight engineers panel (UAL puts the warning light check in the flight crew's checklist); No calibration records of power tools used to open cargo doors; UAL could not verify if SB concerning door shrouds was complied with; one line of text which stated the lock inspection requirements from AD 88-12-04 was not incorporated into UAL's maintenance procedure

Inadequate Design (Yes)- Deficiency in design of cargo door locking mechanisms that allow defects and damage to occur and inaccurately show the door is locked

Inadequate Resources (Yes)- Inadequate FAA PMI/Maintenance inspectors for workload

Supervisory

Inadequate Supervision (Yes)- Inadequate supervision of cargo door maintenance and inspections particularly following several discrepancies the months prior; Failure to rig cargo door; No one noted the clerical discrepancy between the work sheets and the requirements of AD-88-12-04 on inspection requirements

Inappropriate Operations (Yes)- Improper task prioritization by delaying the completion of the terminating actions of Alert SB 52A2206 (Rev 3) and AD-88-12-04 (The NTSB even said that there was no evidence that United had intended to comply with the terminating action of the Alert SB until it was mandated by the FAA).

Uncorrected Problem (Yes)- Cargo Door was not properly rigged following recurrent cargo door problems that were not adequately repaired or identified through trend analysis.

Supervisory Misconduct (No). This may be possible from the lack of evidence/intent in SB completion described above in Inappropriate Operations, but there is no evidence that it was deliberate either.

Maintainer Conditions

Readiness

Training/Preparation (Yes)- Documentation and training on use of the view ports to confirm cargo door locks would have prevented this accident; No documentation or procedure was provided to conduct a required inspection of door locking mechanisms following manual operation of the door and subsequent restoration to electrical equipment (AD 88-12-04)

Working Conditions

Environment

Lighting/Light (No). Flashlights were utilized during darkness.

Equipment

Damaged/Unserviced (No). (Door was damaged, but the equipment was all useable)

Unavailable/Inappropriate (Yes)- Use of air-driven torque limiting screwdriver to open electrically inoperative cargo doors (Report does not state how this directly affected the accident, however)

Dated/Uncertified (Yes)- Air-driven screwdrivers were supposed to be calibrated every six months but no documentation proved that it had been done

Maintainer Acts

Error

Attention/Memory (No). The cargo door problems were noted several times so the maintenance personnel were attentive to problems, unfortunately the repairs were ultimately ineffective

Judgment/Decision-Making (Yes)- Multiple opportunities existed to re-rig the cargo door in response to door discrepancies during the previous months but the corrective actions chosen proved insufficient

Knowledge/Rule Based (Yes)- Inspection requirements were mistakenly not incorporated into manuals; Use of view ports for lock verification was not a procedure or policy

Skill/Technique (Yes)- Previous door repairs were inadequate and were not determined to be a rigging failure

HFACS-ME (Aloha - B737, 1989)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
Working Conditions	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
Maintainer Acts	Workspace	- Confining	- Obstructed	- Inaccessible
	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Management Conditions

Organizational

Inadequate Processes (Yes)- Aloha's flight hour vice flight cycle maintenance program; FAA/Aloha segmented D inspection and ¼ sampling; lack of FAA guidance on AMT training/NDI certification; Boeing/Aloha/FAA relationship and corrective action on manufacturer's inspection results; FAA modification process for AD; Aloha's failure to follow through on their own findings of corrosion

Inadequate Documentation (Yes)- FAA AD weakened the intent of the SB; AD poorly written and subject to misinterpretation; Aloha did not have 4 of the 9 SBs incorporated; Aloha Production and Planning failed to provide further guidance to inspectors on ADs and SBs.

Inadequate Design (Yes)- Lap joints susceptible to disbonding due to possible manufacturing difficulties and inadequate fuselage cycle testing (see NTSB Conclusions 9,10,11)

Inadequate Resources (Yes)- Lack of spare aircraft (time constraints); no engineering department or program for QA liaison with qualified engineers; FAA staffing of adequately trained PMIs

Supervisory

Inadequate Supervision (Yes)- The quality of inspections; failure to notice and correct aircraft discrepancies; poor supervision of maintenance documentation

Inappropriate Operations (Yes)- Procedural confusion on training/logging of eddy current inspections; selection of inspectors based upon seniority vice skill

Uncorrected Problem (Yes)- Failure to correct corrosion deficiencies discovered during Boeing's inspection

Maintainer Conditions

Medical

Mental State (Yes)- Tedious rivet inspection; Expectation of “passing” results; Time pressure to meet daily flight operations; Possible anxiety with use of ropes during inspections

Physical State (Yes)- Fatigue of inspections (climbing scaffolding, carrying equipment, using ropes)

Limitation (No). Aloha inspectors/maintainers had no physical restrictions to the tasks addressed in this accident

Crew Coordination

Communication (Yes)- Lack of verbal passdowns and written documentation of eddy current inspections; Poor communication between management and inspectors on AD/SBs

Assertiveness (Yes)- The second inspector could have demanded to see an eddy current entry; no one was assertive on questioning the corrosion and inspection practices

Adaptability/Flexibility (Yes)- Management/FAA/inspector acceptance of inadequate D inspection scheduling to meet flight schedules; “acceptance” of corrosion/defects on a majority of aircraft; poor handling of AD/SBs within airline

Readiness

Training/Preparation (Yes)- Inspectors had only a two hour Boeing course and OJT

Certification/Qualification (Yes)- There was no requirement for NDI certification (a failure of the system, not the individual)

Working Conditions

Environment

Lighting (Possible). A bright light was carried for inspections, but the report stated that the task of examining rivets “was worse when temperatures and lighting were not optimal”. This is certainly a hazard, but not determined to be a factor at this point.

Weather/Exposure (Possible). Weather was not a factor airborne (Conclusion #3), but it is only referred to vaguely as a condition that might affect inspector performance. It is another hazard to be addressed.

Environmental Hazards (Possible). Falls are certainly possible while carrying lights/meters/etc. on scaffolding and especially when relying on ropes attached to the rafters. No one actually fell, however, it may have made some inspectors uncomfortable which could be a distraction and an unsafe mental state (fear)

Equipment

Unavailable/Inappropriate (Yes)- Scaffolding, mobile lifts, etc. were lacking if inspectors had to rely on ropes

Workspace

Obstructed (Yes)- Cracks are less visible under lap joints or under several layers of paint

Inaccessible (No).. Accessibility may be difficult during inspections on top of the aircraft, but it could be done

Maintainer Acts

Errors

Attention/Memory (Yes)- Inspectors/maintainers did not notice the cracks prior to flight; Failure of any airline employee to notice the crack, especially when it was visible by the boarding passenger; Possible memory failures could have occurred if the crack was noticed by employees but never reported; Inspector may have remembered conducting an eddy current inspection, but may not have (no documentation)

Knowledge/Rule Based (Yes)- NDI inspector was unable to articulate corrosion inspection requirements; Inspectors had differing perceptions on documentation requirements

Skill/Technique (Yes)- NDI inspector's skill level was inadequate

Judgment/Decision-Making (Yes)- Failing to seek clarification on AD/SBs; QA/Maintenance personnel misjudged the effects of extensive corrosion, multiple skin repairs, and numerous deferrals

Violations

Routine (Yes)- Aloha Maintenance routinely deferred corrosion work without recording the basis. As a willful decision that remained uncorrected, this would fall under routine violations vice errors

Infraction (Possible). There was no specific instance of a single individual breaking a rule to save time or effort. However, further investigation is encouraged on the circumstances surrounding the inspector's claim that an eddy current inspection was conducted, considering that there was no documentation and detectable cracks were not discovered

Exceptional (No). There was no conscious violation of safety of flight rules or false documentation of inspections

Fragrant (No). There was no willful attempt to break rules with total disregard for the consequences, or attempt to cause death, injury, or aircraft damage

HFACS-ME (Eastern - L1011, 1983)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Management Conditions

Organizational

Inadequate Processes (Yes)- FAA maintenance inspectors failed to assess the significance of previous incidents involving master chip detectors and to take effective surveillance and enforcement measures to prevent reoccurrence; Eastern failed to adequately assess the significance of similar reported occurrences and take effective action; Communication, Training, and Supervision within Eastern's Maintenance organization were inadequate in ensuring maintenance problems (chip detectors) were correctly addressed and procedures followed; O-ring installation on the chip detectors before they were issued to the mechanics was not in accordance with Eastern's procedures or standardized; chip detector issue and turn in procedures

Inadequate Documentation (Yes)- Although the Work Card was sufficient and clear in mechanic installation of O-rings, the card did not specify how long to motor the engines for leak checks (the mechanics incorrectly believed that a shorter time was sufficient)

Inadequate Design (No). Chip detectors were adequate, the failure to install o-rings by the mechanics caused the oil leakage

Inadequate Resources (Yes)- Flight Safety Office within Eastern was understaffed causing a decreased ability to analyze trends in chip detector issues, etc.

Supervisory

Inadequate Supervision (Yes)- O-ring omission prior to the accident was not discovered; Manual/Work Card use not supervised adequately or enforced; O-ring installation and issue procedures were unknown to maintenance supervisors; Use of headlights for nighttime chip detector removal should have been corrected; Supervisors blamed personnel for each chip detector error without adequate examination of the causes and trends; Supervisors assumed instead of verified training and procedure change notification

Inappropriate Operations (Yes)- Information not used (procedures /manuals) in chip detector issue procedures, o-ring installation, and trend analysis; Unrealistic expectation of improved mechanic performance through punishment without a review of training/procedures; Use of bulletin boards without any verification of dissemination to deliver policy/procedure changes; No training provided on Work Card 7204

Uncorrected Problem (Yes)- Known chip detector hazards and routine lack of procedure use was inadequately assessed and controlled

Supervisory Misconduct (Yes)- Routine failure to enforce Work Card requirements and Training

Maintainer Conditions

Medical

Mental State (Yes)- Complacency was likely because both mechanics involved in the accident had performed over 100 chip detector changes in which o-rings were already on the chip detectors; False sense of chip detector preparation because of “serviceable tag” on the part box

Crew Coordination

Communication (Yes)- Assuming that bulletin boards were adequate for procedure modifications/training; Mechanics took chip detectors from supply without any question or discussion when they did not find them in their normal location for issue on the foreman’s desk; Mechanics assumed that tagged parts were ready for installation; Mechanics were not adequately informed of procedural changes

Adaptability/Flexibility (Yes)- Chip detector issue, o-ring installation, and procedure changes were not adequately communicated within the entire maintenance organization which caused further confusion, assumption, and lack of clarification; Mechanics errantly assumed chip detector preparation were complete because of previous routine; Use of headlights was inappropriate as a light source; Mechanics took parts from supply for the first time and did not discuss the change in routine with anyone else

Readiness

Training/Preparation (Yes)- Mechanics never read the required bulletin board Special Training Procedure 49-81; No additional training was given; Chip Detector issue changes were a surprise to the mechanics; Mechanics never installed o-rings because they were always previously prepared for use

Working Conditions

Environment

Lighting/Light (Yes)- Use of headlights for chip detector maintenance was inadequate

Equipment

Unavailable/Inappropriate (Yes)- Using headlights or “feel” to install chip detectors instead of verifying o-rings installation with flashlights was inappropriate for the task

Dated/Uncertified (No). No tool/equipment certification issues were noted. The chip detectors, though acquired from supply without o-rings, were ready for issue (the mechanics failed in their responsibility to ensure that the o-rings were installed)

Workspace

Confining (Yes)- Mechanics had to reach within confined areas to install chip detectors and relied on “feel” for installation

Obstructed (Yes)- Chip detectors were not directly visible behind access doors, particularly when handling parts, so the mechanics relied upon feel for installation (this does not affect o-ring use because that required verification before chip detectors were installed)

Maintainer Acts

Error

Attention/Memory (Yes)- Mechanics did not notice missing o-rings

Judgment/Decision-Making (Yes)- Mechanics did not question packaging differences with the accident chip detectors; Mechanics assumed chip detectors acquired in a “non-routine” manner were adequate for installation; Neither mechanic chose to consciously examine the chip detectors for proper o-ring installation even though both knew that they were ultimately responsible

Knowledge/Rule Based (Yes)- Procedure changes were not known; Training was not provided to the task; Mechanics did not know the time requirements for leak check engine motoring

Skill/Technique (No). The chip detectors and o-rings weren’t damaged by insufficient skill in installation, the mechanics simply failed to know or follow procedures

Violations

Routine (Yes)- Routine violation of Work Card requirements was done through poor judgment, routine expectation that o-ring installation was already accomplished, and failure to understand the consequences

HFACS-ME (Eastern - L1011, 1981)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Management Conditions

Organizational

Inadequate Processes (Yes)- Inspection and maintenance practices failed to discover alignment problem; Eastern changed their oil sampling program after the accident

Inadequate Documentation (No). The NTSB Recommendations detailed various changes to manuals, but this was not for errors in documentation. The changes were for improved Processes (overhaul process improvements) and engine Design (bolt sizes, etc.). [See Inadequate Processes and Inadequate Design.]

Inadequate Design (Yes)-. Oil supply was a “slinger” type which was changed after the accident to a twin axial oil jet design; IPLB inner race retention bolts will be replaced with stronger bolts and higher torque; a fan retention device was recommended; containment design issues; front sealing arrangement

Supervisory

Inadequate Supervision (Yes)- Failure to discover alignment problem during engine maintenance.

Working Conditions

Environment

Lighting/Light (Unknown). Although there is probably no environmental lighting issue, the lighting available for inspections was not adequately discussed.

Maintainer Acts

Error (Possible). There was an error in alignment which caused the oil leaks...but it is unknown why. It would be easy to suggest a problem in skill/technique, but there is no identification of the personnel who conducted the work or their work experience. The problem could just as easily be in attention, judgement, knowledge, or any error combination.

HFACS-ME (Air Florida - DC-10, 1981)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Notes: This NTSB report does not address any “whys” for the origin of the FOD or the maintenance/inspection practices that failed to discover it. The report simply describes the undiscovered FOD as the cause of the engine failure while the remainder of the report thoroughly discusses “what if” scenarios had the aircraft been airborne with similar or worse damage from the uncontained engine. This is more of a hazard report than an investigation of the actual accident. The recommendations do not discuss the FOD at all or provide any information that would prevent its reoccurrence. The NTSB report has only two recommendations, and they simply address uncontained engine failure improvements (an effect of the accident).

Management Conditions

Organizational

Inadequate Processes (Yes)- QA/Tool or Parts Control/FOD procedures are inadequate if this FOD was undiscovered for so long. The NTSB report unfortunately does not address Maintenance Procedures/Documents/Working Conditions/Maintainer practices, so these areas need further investigation to prevent future occurrences.

Inadequate Design (Yes)- Redesign will probably not contain a “chunk failure”, but the report’s Analysis and Recommendations discuss future improvements to engine containment

Supervisory

Inadequate Supervision (Yes)- Inspection at the local level is inadequate if FOD is undiscovered for so long; Tool/parts inventories are probably not adequately supervised as well if FOD was a bearing inner race or tool as speculated in the report

Maintainer Acts

Error

Attention/Memory (Yes). The FOD, suspected of being a tool or an extra No. 5 bearing inner race, was either left in the engine (an attention or memory failure) or was of unknown origin but missed during maintenance and inspections (attention). The report does not detail the maintenance/inspection practices, however.

Judgment/Decision-Making (Unknown). FOD was removed from between the variable stator vanes and actuator arm one week prior to the accident. Engine was checked for visible damage but none found. The report did not discuss whether the “inspection” was procedurally correct or adequate following that discovery. This should certainly be investigated further.

Violations (Possible).

The NTSB report does not investigate any of the “whys” involved with the FOD left in the engine so a violation of any one of the four types could be a remote possibility.

HFACS-ME (American - DC-10, 1979)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Management Conditions

Organizational

Inadequate Processes (Yes)- FAA surveillance and reporting systems of improper maintenance procedures; Communication between the operators, manufacturer and the FAA on previous maintenance damage incidents; American and other carriers removed engines and pylons as a single unit instead of separately as described in the SB for reasons of efficiency, safety and economy; Engineering analysis of this carrier modified procedure was inadequate; Training was limited to OJT on this modified procedure; NTSB thought aircraft certification regulations may have been inadequate in addressing multiple malfunctions from a single failure; (McDonnell-Douglas Quality Control of pylon line assembly procedures were questioned but not found causal to the accident); No post-maintenance inspections were required by American's Engineering Order; Inadequate reporting of maintenance accidents

Inadequate Documentation (Yes)- Operational Occurrence Report (describing other DC-10 occurrences) described damage but not how the aircraft were damaged; American personnel responsible for pylon maintenance were not aware of the findings of the Operational Occurrence Report (dissemination issue); Engineering Change Operation (ECO) procedures were difficult to accomplish with the forklift so the maintainers altered the sequence; ECO had incomplete guidance on forklift use and was not in accordance with the SB; No inspection requirements were specified on ECO

Inadequate Design (Yes)- NTSB cited inadequate design of the pylon attach points and leading edge slat system which were vulnerable to maintenance damage; Minimal clearances made maintenance difficult to perform; System interrelationship and failure analysis were within certification requirements, but the NTSB felt that the regulations should have required further study of multiple failure design

Supervisory

Inadequate Supervision (Yes)- Engineering and supervisory personnel did not monitor the performance of the ECO to insure that it was being accomplished properly or check for unforeseen maintenance task difficulties

Inappropriate Operations (Yes)- Use of a forklift for the engine/pylon removal was inappropriate with unrealistic expectations; Task training was limited to OJT; The inspector had not received any training with regard to the modified procedures; Procedures were modified without feedback communications

Supervisory Misconduct (Yes)- ECO procedures were modified and the difficulties were not communicated to engineering

Maintainer Conditions

Crew Coordination

Communication (Yes)- Maintenance personnel did not inform engineering or quality control about their difficulties in removing the engine/pylon assemblies.

Adaptability/Flexibility (Yes)- Modification of the SB to use a forklift for simultaneous engine/pylon removal was a failure in trying to adapt ease and speed of maintenance with scheduled maintenance; Forklift ran out of fuel which allowed a slow lowering of the forks which increased the force on the pylon flanges; Modification of ECO steps was more efficient but further increased the loads on the flanges

Readiness

Training/Preparation (Yes)- New procedure was not in accordance with manufacturer's SB so that training was limited to OJT and experimentation; Inspector had not received any training on the modified procedures

Working Conditions

Equipment

Unavailable/Inappropriate (Yes)- Use of a forklift to precisely raise and lower an engine and pylon (as a single unit) was inappropriate.

Workspace

Confining (Yes)- The very low tolerance for error near the attaching points while using the forklift. Task was described as very difficult to accomplish.

Maintainer Acts

Error

Attention/Memory (Yes)- Forklift ran out of fuel during task which then caused forks to creep; Despite extreme tolerances and use of forklifts, no one noted the damage done to the flanges

Judgment/Decision-Making (Yes)- ECO use of forklift for engine/pylon removal was poor judgment at the organizational level, but the further changes to those procedures by the mechanics increased the likelihood of damage to the flanges; Failure to notify engineering and QA of difficulties in accomplishing the engine/pylon removal was an example of poor judgment; Two mechanics noted that the upper lug of the aft bulkhead rested against the bolts attaching the wing-mounted clevis but failed to judge that the flange was deformed to the point of inducing an overload crack

Knowledge/Rule Based (Yes)- Procedures inadequate with a new task; Training not provided

Skill/Technique (Yes)- This was a new procedure conducted with inadequate equipment. Skillful use of forklifts was required due to the minimal tolerances. The mechanics described the task as difficult.

Violations

Infraction (Yes)- ECO procedures reordered by mechanics without notifying engineering

HFACS-ME (Mercer - DC-6, 1976)

Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision-Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

Notes: This is a VERY SHORT report. More detail is needed. Also, the post-crash fire was caused by the fire crews while cutting into the aircraft. **Management Conditions**

Organizational

Inadequate Processes (Yes)- Mercer / FAA did not check for adequate publications at the certified propeller overhaul facility

Inadequate Documentation (Yes)- Despite the fact that the most recent manuals and changes for the Curtiss-Wright propeller were published in the late '50s and early '60s, Mercer had the appropriate prop manuals with changes, but did not ensure that their contracted overhaul facility had the changes which specified inspecting the entire blade

Inadequate Design (Yes)- Although an old propeller with appropriate inspection techniques for years of use, the NTSB cited in their Analysis section that the cracks formed "in the brazing material that intersected mismatches formed during the manufacture of the blade shell" (this was not found in the NTSB's Conclusion or Recommendations, however)

Supervisory

Inadequate Supervision (Yes)- Supervisors did not ensure that appropriate manuals were available or question the practice of leaving the deice boots on during Magnaflux inspections; Inspections were not documented thoroughly

Maintainer Conditions

Readiness

Training/Preparation (Yes)- Magnaflux inspectors were not provided with the updated changes to the Curtiss-Wright manual or given guidance on removing the deice boots for Magnaflux inspection

Maintainer Acts

Error

Knowledge/Rule Based (Yes)- The blade deice boots were not removed because the inspectors were not trained or given further documentation to do otherwise.